# WATER RESOURCES INVESTIGATION

## WOONSOCKET
## LOCAL PROTECTION PROJECTS

*BLACKSTONE RIVER, WOONSOCKET,*
*RHODE ISLAND*
*BLACKSTONE RIVER BASIN*

# SITUATION REPORT



*Department of the Army*
*New England Division, Corps of Engineers*
*Waltham, Mass.*

**JUNE 1977**

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The situation report includes the results of a review of the operational adequacy of the Woonsocket Local Protection Projects and presents hydrologic and stability investigations to determine the need for modifying the existing flood control system.
The stability and hydrologic analyses revealed that riprap in the Upper Woonsocket Local Protection Project (completed in 1960) was found to be performing satisfactorily except where vandalism has occurred. The city of Woonsocket has been replacing riprap on these denuded areas and is, in general, using larger size stone in an effort to discourage further vandalism.
It is concluded that the overall project is operating adequately and functioning in accordance with project design and construction. The project meets current design criteria and the present needs and desires of local interests. No further studies are recommended at this time.

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WOONSOCKET LOCAL PROTECTION PROJECTS

BLACKSTONE RIVER

WOONSOCKET, RHODE ISLAND

# SITUATION REPORT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS 02154

June 1977

# SYLLABUS

This situation report includes the results of a review of the operational adequacy of the Woonsocket Local Protection Projects and presents hydrologic and stability investigations to determine the need for modifying the existing flood control system.

The stability and hydrologic analyses revealed that riprap in the Upper Woonsocket Local Protection Project (completed in 1960) was found to be performing satisfactorily except where vandalism has occurred. The city of Woonsocket has been replacing riprap on these denuded areas and is, in general, using larger size stone in an effort to discourage further vandalism.

In the Lower Woonsocket Local Protection Project (completed in 1967), foundation and materials and hydrologic analyses revealed that the stone size at the entrance of the conduit of the Peters River is not adequate to withstand a project design flood. Further consideration to modifying the approach channel will be done under the Operations and Maintenance Program, Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures. Along the Mill River channel area two catch basins which convey water from a small stream to the Mill River should be encased in a concrete box with a Trash rack to prevent the conduit from being blocked during flood flows. This modification is a local responsibility therefore the city of Woonsocket will be informed of our recommendation. Finally, bank erosion on the right bank of the Blackstone River between the two projects was noted but does not present any threat to adjacent properties at this time. Future inspections of this area will be made in conjunction with the regular semi-annual project inspections to monitor that problem.

It is concluded that the overall project is operating adequately and functioning in accordance with project design and construction. The project meets current design criteria and the present needs and desires of local interests. No further studies are recommended at this time.

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## BLACKSTONE RIVER BASIN

## Situation Report

### THE STUDY AND REPORT

#### Purpose

There is a continuing need to assure that existing Corps projects are in accord with present day needs, that they are structurally sound and remain operationally adequate. Four specific review programs employed by the Corps for this purpose are as follows: (1) Semi-annual inspection of the project to insure local compliance with the operation, and maintenance agreements (2) Periodic Inspection and Continuing Evaluation Program which reviews project features to assure that they are structurally adequate (3) the Section 216 Program which reviews the operational adequacy of the project and also determines if there is a need to modify the project for other purposes and (4) Situation Reports similar to this one which reviews the operational adequacy of the project to determine if major problems exist which require detailed studies under authority of Section 216 of the 1970 Flood Control Act. This review of the completed Woonsocket Local Protection Projects at Woonsocket, Rhode Island was initiated because of changed conditions and new design criteria since project completion. The Upper Woonsocket Local Protection Project was completed in 1960 and the Lower Woonsocket Local Protection project was completed in 1967.

#### Scope of Study

This is a report of survey scope which focuses on the hydrologic and stability investigations and their conclusions as a basis for determining whether additional studies or modifications are needed. During its preparation contacts and meetings were held with local interests to determine whether the constructed project meets their present needs or if any reformulation is desired for other project use.

The items used in the technical review consists of as-built construction drawings, project reports, gaging station records and the information obtained from reconnaissance investigations of the project site. Office studies consisted of updating the original hydrologic and stability analyses to determine how changes in design criteria have affected the operational adequacy of the project.

### Coordination with Local Interests

Coordination of this study was limited to the local level.

On 17 July 1975, a field investigation and meeting with officials of the city of Woonsocket, Rhode Island was held to inform the city of our ongoing study and to determine if local officials were aware of any problems which had developed as a result of our project. Problems which were cited are discussed in general in subsequent paragraphs under the heading "Status of Existing Plans and Operations." The need for modifying the project for other purposes was also discussed and later abandoned after city officials indicated little interest in this regard.

## THE STUDY AREA

### Project Description

Upper Woonsocket Local Protection Project

The project is located in northeastern Rhode Island, on the Blackstone River and extends from the South Main Street Bridge, in the center of Woonsocket, upstream 8,300 feet to the vicinity of the Massachusetts - Rhode Island state line. It was designed to provide complete protection to adjacent properties from a recurrence of the record August 1955 flood of 26,000 cfs. The project includes channel improvements, a reinforced concrete floodwall, earthen dikes with stone slope protection a pumping station and the replacement of the original Woonsocket Falls Dam with a tainter-gated structure.

The channel improvements consisted of widening, deepening, and straightening the Blackstone River along the entire 8,300 feet and included the excavation or deepening of the rock spillway discharge channels through the arches of the South Main Street Bridge.

# UPPER WOONSOCKET LOCAL PROTECTION PROJECT

LOOKING UPSTREAM ALONG BLACKSTONE RIVER


LOOKING UPSTREAM AT WOONSOCKET FALLS DAM

Approximately 1,300 feet of reinforced concrete floodwall and earthen dike are provided in the Singleton Street area. A pumping station, to provide for interior drainage and runoff from higher ground, was constructed within the enclosed area. Stone slope protection is provided on the riverside face of the earthen dike. The dikes and floodwall are designed to provide 3-feet of freeboard above design flood levels.

A primary element of the improvements is the new Woonsocket Falls Dam. It consists of a concrete overflow section with a total length of 266 feet with four 50-foot long by 10.1-foot high tainter gates. In the normal operating position the gates are closed to maintain a process water pool elevation of 148.1 feet msl. With the gates raised the spillway will pass the project design flood (30,000 cfs) with a head pool at approximately 153 feet msl. The gates are raised in anticipation of, and during flood flows to lower upstream river stages.

Other improvements included the replacement of a highway bridge, a railroad bridge and four sewer siphons. A second railroad bridge was modified to provide the required channel width. A general plan and profile of the project is shown on Plate A-5.

Lower Woonsocket Local Protection Project

Located on the Blackstone River in the city of Woonsocket the project provides protection against flooding from the Blackstone and the tributary Mill and Peters Rivers, within the limits of Woonsocket. It consists of approximately 6,000 feet of dikes and floodwalls, 2,850 feet of channel improvements, two pumping stations, a modification to a footbridge, the removal of two dams, plus miscellaneous utility works. Provisions for containing the Peters River through Woonsocket to its confluence with the Blackstone, consisted of the construction of dikes and floodwalls leading to a 10-foot by 17-foot pressure conduit. The Mill River was similarly contained by the construction of a twin 12 by 21-foot pressure conduit which required dikes and walls extending from the conduit entrance to high ground. A general plan and profile of the project is shown on Plates A-6 and A-7. More detailed discussion of specifics can be found in the feature Design Memorandums for both projects.

### Environmental Setting

The Blackstone River watershed above Woonsocket Falls Dam lies in south central Massachusetts and northern Rhode Island. Generally elongated in shape, the basin stretches northward approximately 32 miles to the vicinity of Worcester, Massachusetts with an average width of 12 miles. The basin extends over 369 square miles occupying the southeastern quarter of Worcester County, Massachusetts and the northern portion of Providence County, Rhode Island.

The headwaters of the Blackstone River originate in the western portions of Holden and Worcester. Kettle Brook flows southeasterly through Leicester and Auburn joining with Beaver Brook at Webster Square in Worcester to form the Middle River. The junction of the Middle River and Mill Brook in the southeastern section of Worcester forms the Blackstone River. Flowing generally southward, the Rivers tributaries, in downstream order, are the Quinsigamond, Mumford, West and Branch Rivers.

The basin is generally hilly and rolling with the higher elevations and narrower valleys located in the northwest portion of the basin. Located throughout the basin are a number of lakes, ponds and reservoirs of appreciable size. The largest lake in the basin is Lake Quinsigamond (surface area 539 acres) located in the eastern section of Worcester and is part of a closely related series of three bodies of water. The other two ponds in the series are Flints Pond with an area of 322 acres, and Hovey Pond with an area of 68 acres. The combined storage of the three is controlled by a dam at the foot of Hovey Pond. Other ponds of significant size in the basin are Manchoag Pond with an area of 360 acres, Whitins Pond with an area of 350 acres and Wallis Reservoir with an area of 250 acres.

## INVESTIGATIONS

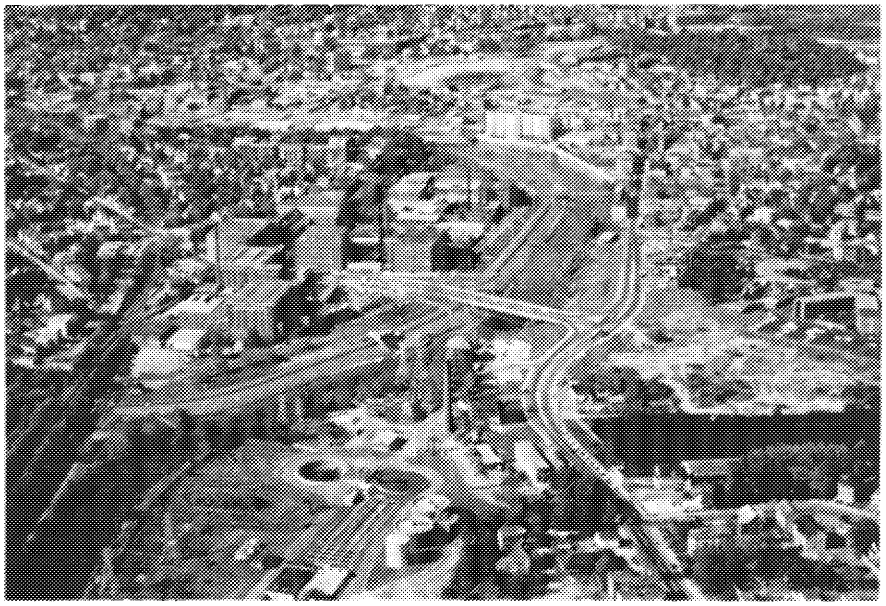
### General

Investigations were made in the areas of hydrology, structures and foundations and materials. The general operation of the projects were evaluated to determine if any significant problems have developed since the projects completion.

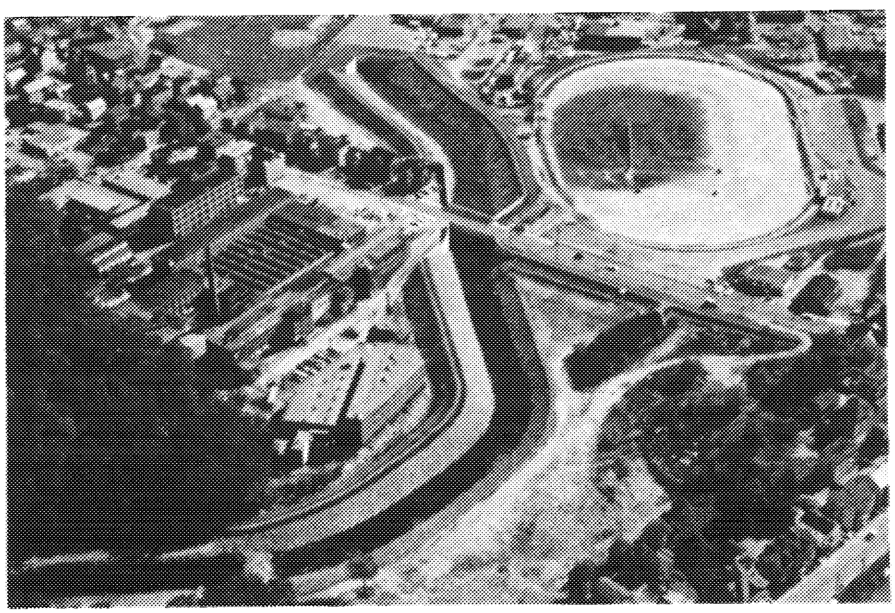
### Hydrology and Hydraulics

A review of the hydrologic and hydraulic adequacy of the Woonsocket Local Protection Projects was made and the results are included in Section A of Appendix 1. The review included an evaluation of the interior drainage facilities and riprap sizing for both projects. From a design viewpoint all project features were found to be adequate although some minor operational problems have developed. These are discussed in the paragraph titled "Problems and Solutions".

# LOWER WOONSOCKET LOCAL PROTECTION PROJECT



LOOKING UPSTREAM ALONG BLACKSTONE RIVER



LOOKING DOWNSTREAM ALONG MILL RIVER AT SOCIAL PARK

## Stability Analysis

The dikes, floodwalls and channels within the project limits were evaluated to determine if recent changes in design criteria have affected the adequacy of the structures. The results of this analysis can be found in Section B of Appendix 1. All the dikes, floodwalls and channels in the upper project were found to be operating adequately. In the lower project the riprap along the approach channel to the Peters River conduit was found to be deficient in size to withstand a standard project flood. A flood of SPF magnitude would cause dislodging of the stone and possible blockage of the conduit. As a result of the March 1968 freshet, some dislodging of stone occurred causing the stone to collect inside the conduit.

## Problems and Solutions

Since completion of the Woonsocket Local Protection projects minor operational problems have developed along both the upper and lower projects. Along the upper project in the vicinity of the Singleton Street pumping station, a section of the channel sideslope has been stripped of riprap by vandals. The proximity of a city playground to this section of channel appears to be the apparent reason. The city of Woonsocket has repaired this area by using a larger size stone. A similar problem has occurred along the Social District dike adjacent to Social Park.

A ramp located approximately 200 feet downstream from the upper limit of the project along the Mill River, was cut to allow access to the channel for the removal of silt from various locations along the channel. As a result, riprap on the side slope was displaced and the natural bank soils are exposed and subject to erosion. No danger is presented to adjacent properties, as the land beyond the top of bank is within the design flood storage area. The potential problem would be progressive ravelling of the riprap and widening of the area subject to erosion. In the event of high flows, this could result in extensive repairs being required. The city has assured this office that now that the silt removal project is completed, the channel slope will be restored to its original condition.

In addition, two catch basins along the Mill River intended to intercept interior runoff for conveyance to the river often become clogged with debris. As a result the interior runoff ponds on the right bank and then flows overland and down the embankment to the channel. This overbank flow could be structurally detrimental to the riprap protection. It is recommended that the city enclose these two catch basins with a concrete box and trash rack which will allow for easier maintenance of the drainage conduit.

Along the Peters River just beyond the project limits the filling of a portion of a pond formed by an old concrete dam at the Mill Street Bridge poses a potential problem. The height of the fill above the water surface is approximately 15 feet. This fill does not directly effect the project on the Peters River. However, because of the fill material the width of the pond is narrowed and should the fill slough off it is conceivable that it might block flows in the river. This could result in an increase in upstream water surface elevations, especially during periods of high flows, and might cause some of the water to "short circuit" the project by flowing down Social Street into the lower Social District area.

Heavy siltation at the Social Street Pumping Station and higher silting at Singleton and Hamlet Stations has developed in recent years. This siltation acts as an obstacle to the full design operation capability of the gates and flap valves at times of heavy runoff. Since this is a local responsibility the city of Woonsocket will be required to remove the silt.

Finally, erosion to the outer bank of the Blackstone River downstream of the South Main Street bridge between the upper and lower project limits has developed since the Bernon and Hamlet Dams were removed in conjuction with construction of the Lower Woonsocket Local Protection Project. The erosion is minor and does not pose a threat to adjacent properties therefore no remedial measures are recommended at this time although future semi-annual inspections would include this area to monitor any future changes or progression.

## CONCLUSIONS

It is concluded that the overall project is operating adequately and functioning in accordance with project design and construction. It meets current design criteria and the present needs of non-Federal interests.

## RECOMMENDATIONS

No further detailed studies are recommended at this time.

# APPENDIX I

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SECTION A

HYDROLOGIC REVIEW

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## WOONSOCKET, RHODE ISLAND

### HYDROLOGIC REVIEW
### AUGUST 1976

1. PURPOSE

The purpose of this study was to present and review the pertinent hydrologic features of the Woonsocket, Rhode Island upper and lower local protection projects, to note possible deficiencies and discuss possible remedial plans of action. A general plan of the projects shown on Plate A-1. The projects were evaluated using current hydrologic design criteria and problem areas which have arisen since completion of the projects, were noted, and hydrologically investigated. This report contains sections on project descriptions, hydrologic background, apparent problem areas and possible remedial actions. It is intended for use as a reference in appraising the need for further engineering study.

2. SUMMARY

As a result of this study it was concluded that both the upper and lower Woonsocket Local Protection Projects meet current hydrologic design criteria. Existing or potential problem areas are discussed in detail in the text. Vandalization of riprap in the upper project was noted as requiring remedial action. Two other problem areas, a ramp cut in the channel side slope and two frequently blocked catch basins, both on the Mill River, are considered within the order of routine maintenance and as such are the responsibility of the city. Personnel of the Project Operations Branch of the Operations Division are aware of these latter two problems and are monitoring their repair. A remaining area, involving the filling in of a portion of a small pond above the project limits on the Peters River, must await the outcome of a current request by the land owner seeking permission to remove the dam forming the pond. Upon disposition of his request, a determination can be made regarding the impact of the fill on flood control.

3. PERTINENT DATA

A. Upper Woonsocket Local Protection Project

(1) Purpose: Local Flood Protection

(2) Location: Blackstone River in northeastern Rhode Island from the Massachusetts - Rhode Island border downstream to the South Main Street bridge in the center of Woonsocket, Rhode Island.

(3) Completed: April 1960.

(4) Improvements: Replacement of an existing dam, 8,300 feet of channel improvement, one pumping station, earthen dikes, and a concrete floodwall.

(5) Watershed Area at Site: Blackstone River above Woonsocket Falls Dam - 369 square miles.

(6) Flood of Record: Blackstone River, Aug. 1955, USGS gage (416 sq mi) 32,900 cfs*
Woonsocket Falls Dam (369 sq mi) 26,000 cfs (est)

(7) Project Design Flood: 30,000 cfs

B. Lower Woonsocket Local Protection

(1) Purpose: Local Flood Protection.

(2) Location: Blackstone, Mill and Peters Rivers in the city of Woonsocket, Rhode Island.

(3) Completed: April 1967.

(4) Improvements: Approximately 5,000 feet of channel improvement, 1,500 feet of concrete floodwalls, 8,000 feet of earthen dikes, two pumpimg stations, approximately 2,330 feet of concrete diversion structures and the demolition of two dams.

(5) Watershed Area at Site: Blackstone River, (USGS gage), 416 sq mi
Mill River 34.7 sq mi
Peters River 12.7 sq mi

(6) Flood of Record: Blackstone River Aug. 1955 USGS gage DA = 416 sq mi, 32,900 cfs*

(7) Standard Project Flood:
Blackstone River - above Mill and Peters Rivers - 33,000 cfs**
Blackstone River - below Mill and Peters Rivers - 40,000 cfs**
Mill River - 8,500 cfs
Peters River - 3,200 cfs

*Abnormal peak resulting from failure of Harris Pond Dam. Natural peak estimated to be 29,600 cfs.
**As modified by West Hill Reservoir.

## 4. BASIN DESCRIPTION

### A. General Physiology

(1) Description of Blackstone River Watershed: The Blackstone River watershed is located in south-central Massachusetts and northern Rhode Island. It is generally elongated in shape, with a length of about 46 miles and an average width of 14 miles. The total drainage area of the basin is 540 square miles and the drainage area at the USGS gage in Woonsocket, downstream of the Mill and Peters Rivers, is 416 square miles. The topography is generally hilly with the higher elevations lying in the western portion. Short steep tributaries in the upper reaches of the watershed and relatively longer ones in the lower reaches tend to synchronize flood discharges all along the main river. A number of swamps, lakes and mill ponds throughout the basin provide some modification of flood flows. The headwater tributary of the Blackstone River is Kettle Brook, which has its origin about seven miles northwest of the city of Worcester, Massachusetts. Kettle Brook is joined by Tatnuck and Mill Brooks in the southern portion of Worcester, forming the Blackstone River which continues in a generally southeasterly direction. Major tributaries of the Blackstone River include:

| River | D.A. |
|---|---|
| Quinsigamond River | 35 sq. miles |
| Mumford River | 58 sq. miles |
| West River | 35 sq. miles |
| Branch River | 96 sq. miles |
| Mill River | 34 sq. miles |

A watershed map is shown on Plate A-2.

(2) Description of Mill River Watershed: The Mill River has its source at North Pond in Milford, Massachusetts and flows in a southerly direction to its confluence with the Blackstone River in Woonsocket. In its 18-mile length, the Mill River has a fall of about 230 feet of which 23 feet occur in its one mile reach within Woonsocket. The basin, which is about 16 miles long and two miles wide, had a drainage area of 34.7 square miles. The basin consists of low rolling wooded hills and broad valleys with scattered lake and swamp areas. These swamps, lakes and ponds have some modifying effect on floods. Several dams on the Mill River within the city of Woonsocket were destroyed during the August 1955 flood. The largest was the 36-foot high Harris Pond dam since reconstructed, located on the Massachusetts - Rhode Island state line. Four subsidiary dams, which diverted water for industrial purposes, were located downstream from Harris Pond. Use of these dams for industrial water supply was largely discontinued before the August 1955 flood and none of these four dams have been rebuilt since the flood.

(3) Description of Peters River Watershed: The Peters River originates at the outlet of Silver Lake which is located about four miles northeast of Woonsocket in the town of Bellingham, Massachusetts. It flows in a general southwesterly direction to its confluence with the Blackstone River at Woonsocket and drains an area of 12.7 square miles. The Peters River has a total fall of 170 feet in its seven-mile length of which 60 feet occur in the first mile and 70 feet occur in the last mile, leaving only a 40-foot drop in the intervening five miles. The flat slope of this intervening area is not conducive to rapid runoff.

B. Climatology

(1) General: The Blackstone River Basin has a variable climate characterized by frequent but generally short periods of heavy precipitation. The area lies in the path of the prevailing "westerlies" and is exposed to cyclonic disturbances that cross the country from west or southwest toward the east or northeast. The area is also subject to coastal storms that travel up the Atlantic seaboard in the form of hurricanes of tropical origin or storms of extratropical nature, often called "northeasters". The winters are moderately severe with near zero temperatures quite common. The summers are rather warm with extreme temperatures reaching the upper 90's.

(2) Temperature: The average annual temperature varies from 48 degrees F. at Worcester to 50 degrees F. at Providence. The average monthly temperature varies from about 71 degrees F. in July and August to about 28 degrees F. in January and February. Freezing temperatures are common from November to March. Extremes in temperature range from occasional highs slightly in excess of 100 degrees F. to infrequent lows in the minus "teens".

(3) Precipitation: The average annual precipitation over the basin is about 41 inches, distributed rather uniformly throughout the year. At Worcester, the maximum monthly precipitation recorded was 18.58 inches occurring in August 1955 while at Providence the maximum was 12.24 inches occurring in August 1946. On several occasions, a minimum monthly rainfall of zero was reported at both stations for the months of May through October.

(4) Snowfall: Most of the precipitation during the winter months in the northern portion of the basin is in the form of snow. The average snowfall varies from approximately 56 inches at Worcester to about 34 inches at Providence. The average water content of the snow cover in the basin is greatest about the first of March. The average water equivalent of the snowpack at this time is about 2 inches with maximums as high as 6 inches.

(5) Storms: The Blackstone River Basin experiences three general types of storms; continental, coastal and those associated with hurricanes. Continental storms originate over the United States and southwestern Canada and move in a general easterly and northeasterly direction. These storms may be rapidly moving, intense cyclones or may be of the stationary type. These are not limited to any season or month but follow one another at more or less regular intervals with varying intensities throughout the year. Of the coastal storms, tropical hurricanes constitute a very important potential for flood producing precipitation from July to October. Coastal storms of an extra-tropical nature differ from hurricanes principally in that they originate off the Carolina coastline. These storms occur most frequently during the autumn, winter and spring months. Thunderstorms may be of local origin or of the frontal type associated with summer storms.

C. Runoff

(1) Discharge Records: There are five U.S. Geological Survey gaging stations in the Blackstone River Basin. Their locations are indicated on Plate A-2.

(2) Stream Flow: The average annual runoff of the Blackstone River at the USGS gage at Woonsocket is 23.8 inches. This runoff represents approximately 50 percent of the annual precipitation. The maximum, minimum and mean monthly runoff in cfs at the gaging station for the period of record through 1974 is given in Table A-1.

TABLE A-1

MONTHLY RUNOFF

BLACKSTONE RIVER AT WOONSOCKET, RHODE ISLAND
(February 1929 - September 1974)
(cfs)

| Month | Mean | Maximum | Minimum |
|---|---|---|---|
| January | 862 | 1,608 | 178 |
| February | 938 | 2,489 | 354 |
| March | 1521 | 4,055 | 734 |
| April | 1395 | 2,640 | 453 |
| May | 848 | 1,782 | 284 |
| June | 563 | 1,837 | 142 |
| July | 319 | 2,450 | 94 |
| August | 269 | 2,690 | 66 |
| September | 323 | 1,970 | 75 |
| October | 340 | 1,997 | 100 |
| November | 586 | 2,230 | 123 |
| December | 794 | 1,608 | 178 |
| Annual | 730 | | |

D. History of Floods

(1) General: Outstanding floods in the Blackstone River Basin may result from early spring storms combined with melting snow such as the flood of March 1936 or from summer or fall storms such as occurred in October 1955, August 1955, September 1954, July 1938 and November 1927. In addition, local thunderstorms can cause serious flash floods on the small streams.

(2) Floods of Record: The flood of August 1955, the greatest flood of record on the Blackstone River, produced peak discharges two times the magnitude of previous maximums. The August flood resulted from 8-12 inches of rainfall accompanying "Hurricane Diane" falling on ground previously saturated by the precipitation of "Hurricane Connie" which occurred only a few days earlier. The flood of March 1936 had two peaks: the first caused by rainfall combined with snow melt, and the second caused by heavy rainfall. Heavy rains during the summer and fall months produced the November 1927 and July 1938 floods. These two floods and also the March 1936 flood were all about the same in magnitude and prior to August 1955 they were the record floods on the Blackstone River. Since completion of the local protection works there has been one flood at least equal in magnitude to those experienced prior to August 1955. Table A-2 lists the seven highest floods recorded at the USGS gaging station on the Blackstone River at Woonsocket.

TABLE A-2

SUMMARY OF HIGHEST EXPERIENCED FLOODS
BLACKSTONE RIVER AT WOONSOCKET, RHODE ISLAND

| Date | Peak Flow (cfs) |
|---|---|
| August 1955 | 32,900* |
| March 1968 | 15,400** |
| July 1938 | 15,100 |
| March 1936 | 15,000 |
| November 1927 | 15,000 |
| September 1954 | 9,400 |
| October 1955 | 8,700 |

*Abnormal peak resulting from failure of Harris Pond Dam on Mill River. Natural peak estimated to be 29,600 cfs.

**Affected by flood storage in West Hill Reservoir. Natural peak estimated to be 16,900 cfs.

(3) Historic Floods: Information concerning major floods in the Blackstone River Basin dates back to the beginning of the 19th century. Except for floods which occurred in the past 30 years, information on past floods is scant and general. A list of floods which occurred prior to the establishment of stream gaging stations on the Blackstone River follows:

HISTORIC FLOODS
BLACKSTONE RIVER BASIN

| | |
|---|---|
| March 1818 | February 1886 |
| March 1876 | September 1887 |
| March 1877 | |

There is no reliable information on the magnitude of these floods. Available records, however, indicate that they all caused damage.

E. Other Corps Projects

(1) Existing Projects: There are three other completed flood control projects in the Blackstone River Basin. These are: (a) the West Hill Reservoir on the West River in Massachusetts, (b) Worcester Diversion Local Protection Project in Worcester, Massachusetts and (c) the Blackstone Local Protection Project in Blackstone, Massachusetts.

(2) West Hill Reservoir: West Hill flood control dam, completed in 1961, is located on the West River about three miles upstream from its junction with the Blackstone River and controls the runoff from 28 square miles of watershed. This reservoir has flood control storage capacity equivalent to 8.3 inches of runoff from its watershed and is operated to reduce flooding downstream of the West and Blackstone Rivers.

(3) Worcester Diversion: This local protection project, completed in 1960, is located in the towns of Auburn and Millbury, Massachusetts. The project consists of a control dam and an ungated tunnel intake structure, a 16-foot diameter tunnel about 4,200 feet long, and an 11,300-foot channel. Flood flows from 30 square miles of the Kettle Brook drainage area are diverted via this tunnel around the central city of Worcester and returned to the Blackstone River at a point approximately 3,500 feet downstream of the Worcester city limits. The diversion provides flood control for Worcester, but has no significant effect on flood flows on the lower Blackstone River.

(4) Blackstone Local Protection Project, Blackstone, Massachusetts: The Blackstone Local Protection Project was completed under the Emergency Relief Act in 1936, this project was restored by the Corps of Engineers after having suffered major damage during the March 1968 flood. This project consists of 860 feet of stonefaced earthen dike tied into the remaining floodwall on the upstream end and into a railroad embankment on the downstream end. Restoration was completed in June 1971.

5. UPPER WOONSOCKET LOCAL PROTECTION PROJECT

A. Project Description

(1) The project is located in northeastern Rhode Island, on the Blackstone River and extends from the South Main Street Bridge, in the center of Woonsocket, upstream 8,300 feet to the vicinity of the Massachusetts - Rhode Island state line. It was designed to provide complete protection to adjacent properties for recurring August 1955 flood of 26,000 cfs. The project includes channel improvements, a reinforced concrete floodwall, earthen dikes with stone slope protection, a pumping station and the replacement of the original Woonsocket Falls Dam with a tainter-gated structure.

(2) The channel improvement consisted of widening, deepening and straightening the Blackstone River for a distance of approximately 8,300 feet. This improvement extended from the vicinity of the Rhode Island - Massachusetts state line to a point slightly downstream of the South Main Street Bridge and included the excavation or deepening of the rock spillway discharge channels through the arches of the bridge. Channel bottom widths vary from 100 to 120 feet with the maximum being controlled by the available waterway between existing structures. Side slopes for the channel are 1 on 2 in earth and 4 on 1 in rock. Rock riprap is provided for the protection of exposed slopes, bridge piers and abutments to prevent erosion.

(3) Approximately 1,300 feet of reinforced concrete floodwall and earthen dike are provided in the Singleton Street area tieing into high ground. A pumping station, to provide for interior drainage and runoff from higher ground, was constructed within the enclosed area. Stone slope protection is provided on the riverside face of the earthen dike. The dikes and floodwall are designed to provide 3-foot of freeboard above design flood levels.

(4) The new Woonsocket Falls Dam consists of a concrete overflow section with a total length of 266 feet. It has four 50-foot long by 10.1-foot high tainter gates. In the normal operating position the gates are closed to maintain a process water pool elevation of 148.1 feet msl. With the gates raised the spillway will pass the project design flood (30,000 cfs) with a head pool at approximately 153 feet msl. The gates are raised in anticipation of, and during flood flows to lower upstream river stages.

(5) Project improvement required the replacement of a highway bridge, a railroad bridge and four sewer siphons. A second railroad bridge was modified to provide required channel width. Plates A-3 and A-4 are general plans of the project and Plate A-5 is a project profile.

B. Standard Project Flood

(1) The development of the Standard Project Flood (SPF) for the Upper Woonsocket Local Protection Project is described in the Woonsocket Local Protection Project Design Memorandum No. 2 Hydrology and Hydraulic Analysis, dated May 1956.

(2) The peak discharge of the developed SPF was 30,000 cfs, equivalent to 81 cfm. Physical and economical conditions precluded the elimination of all damage during this discharge. However, this flow was adopted as the project design flood for the major features of the local protection project. Complete protection is provided for a recurring August 1955 flood (26,000 cfs) with some low lying industrial areas experiencing some inundation during the Project Design Flood.

(3) During the design of the Lower Woonsocket Local Protection Project a revised SPF for the Blackstone River at Woonsocket was developed. This revised SPF is 26 percent greater than the former SPF described in the Interim Survey Report of May 1957, and is 47 percent greater than the record flood of August 1955 (neglecting effect of dam failure on Mill River). The higher discharge in the SPF is attributed to the higher peak of the adopted unit hydrograph. In the 1957 report, and previously used in the Hydrology Design Memorandum dated May 1956 for the local protection project in upper Woonsocket, the 6-hour unit hydrograph had a peak value of 4,270 cfs compared with the 5,700 cfs now considered applicable. There was no change in the standard project storm nor its orientation over the Blackstone River Basin.

C. Interior Drainage

(1) Interior drainage facilities were provided for approximately 31 acres of a highly industrial interior area in the vicinity of the Singleton Street bridge. Both gravity outlets and a pumping station are provided. During intense storms the system would receive additionally about half of the runoff from 34 acres lying east of Harris Avenue in the Gaskill Street section. There has been little change in the hydrologic character of these interior areas since project completion.

(2) The gravity outfalls were sized to be compatible with present and expected future collector drain capacities and were sized for a 10-25 year frequency storm runoff rate of 75 cfs, assuming a 50 percent contribution from the high level area. The Rational formula was used to compute runoff with a composite "C" of 0.6 and a time of concentration of 45 minutes. The pumping station capacity was based on an analysis of rainfall rates during past floods and interior damage potential versus station cost. The selected station capacity was 33 cfs with a design river level of 153 feet msl. This is equivalent to a runoff rate of approximately 1 inch per hour from the low lying industrial area. Due to the moderate rate of rainfall used, no runoff from the high level area was considered in sizing the pumps.

(3) The adequacy of the discharge capacities for the interior drainage facilities were reviewed using current criteria given in EM 1110-2-1401, "Interior Drainage of Leveed Urban Areas". The protected area was classified as a Class I, concentrated commercial-industrial section requiring that ponding not exceed stage B (intermediate design objective) during a 10 year frequency storm runoff. State B ponding is defined as the depth of water in secondary streets, parking lots, yards or driveways causing temporary inconvenience or nuisance, or causing substantial property damage to a moderate number of properties. Although no ponding was considered during the original design of the project, some very infrequent ponding is considered acceptable within the protected area due to the large amount of low lying open area in the mill parking lots and yards. For the Singleton Street area an elevation of 158.0 feet msl, giving approximately one foot of ponding, was considered as stage B. This elevation precludes any danger to the pumping station which has a first floor elevation of 158.5 feet msl. The design pumping capacity, in combination with the shallow ponding that would take place if capacity is exceeded, is considered adequate to meet todays design requirements. It is therefore concluded that the original drain capacities more than meet present day criteria as presented in the referenced EM.

(4) The pumping station is required for discharging interior runoff whenever river stage opposite the station exceeds elevation 152.1 feet msl (river gage +4.0'). Such a stage has an approximate annual frequency of 20 percent. Since the project was completed in 1960 the pumping station has been operated at various times due to minor floods on the Blackstone and at least once in 1968, for a moderate size flow. No operational problems arose during these periods of pump activation.

D. Woonsocket Falls Dam

(1) The Woonsocket Falls Dam is a concrete structure having four 50-foot spillway weirs with 10.1-foot high tainter gates and a short non-overflow right abutment section across an abandoned canal. The dam is founded on a bedrock and is intended to pass rather than impound flood flows. The new dam replaces a former structure having a fixed crest. Normal stream discharge flows over the tainter gates or through the canal on the left bank to water-using industries. Crest of the dam is elevation 138.0 and top of gates are at elevation 148.1 (stage 0.0), when the gates are in a closure position.

(2) A service bridge provides truck access from Glenark Street at the right or west abutment. A generator building on the right abutment beneath the service bridge contains electrical controls, river gage, standby gasoline-electric generator and other equipment. A catwalk beneath the service bridge is provided for access to gate hoisting machinery and gate controls.

(3) When river stages are expected to exceed +2.5' at the dam the dam operator prepares for operation as per his instructions in the O&M Manual. The proper regulation of gates during floods will have no appreciable effect on downstream flood stages. Minor fluctuations will be experienced at points immediately downstream, but these fluctuations will become quickly dampened as the flow passes further downstream.

(4) Since completion of the project the dam has been operated on an annual basis for the purpose of controlling upstream river stages. Some minor problems have arisen during these operating periods or during inspection periods. Vibrations occurring during low head (6"-9") discharge over the gate crests were traced to oscillations developed from the instability of the falling thin sheet of water. The oscillations were stopped by adding deflectors to the gate crest breaking the 32-foot sheet of water into approximately 5-foot lengths. The failure to follow proper maintenance scheduling resulted

in two gates being inoperative due to failure of the hoisting cables in the winter of 1971-1972. Immediate replacement of all cables was necessitated in order to insure the project of operational capability for the spring flows. Strict adherence to preventative maintenance schedules and inspections to locate trouble spots should prevent a recurrence.

E. Riprap Analysis

(1) Using current tractive force criteria for the sizing of riprap, the resulting $D_{50}$ minimum sizes were computed at selected stations throughout the length of the project. The results of this analysis are listed in Table A-3. This hydraulic analysis and resulting $D_{50}$ minimum information is presented for further investigation of existing riprap adequacy by the Foundations and Materials Branch of the Engineering Division. Current tractive force design procedure is set forth in (a) Draft Report, "Criteria for Graded Stone Riprap Channel Protection", April 1966, (b) ETL 1110-2-60, June 1969 (c) ETL 1110-2-120, May 1971 and (d) EM 1110-2-1601, July 1970.

(2) The riprap for the Woonsocket Local Protection Project was designed and installed prior to current OCE criteria, and no major flows approaching design conditions have occurred which would evaluate the existing riprap under design hydraulic forces. It is noted, however, that the existing riprap, even if adequate hydraulically, has proven inadequate in size with regard to vandalism. As a result of vandalism (rock throwing), maintenance of the riprap by the city has been above that normally expected. In future designs or modifications in urban areas, consideration will be given to providing minimum stone sizes sufficiently large to discourage vandalism. The extent of vandalism along the project is varied but most pronounced at points of easy access to the project.

6. LOWER WOONSOCKET LOCAL PROTECTION PROJECT

A. Project Description

(1) The project located on the Blackstone River in the city of Woonsocket in northeastern Rhode Island provides protection to the city against flooding from the Blackstone and the tributary Mill and Peters Rivers, within the limits of Woonsocket. The project consists of approximately 6,000 feet of dikes and floodwalls, 2,850 feet of channel improvements, two pumping stations, a modification to a footbridge, the removal of two dams, plus miscellaneous utility works. Provisions for containing the Peters River through Woonsocket to its confluence with the Blackstone, consisted of the construction of

TABLE A-3

HYDRAULIC ANALYSIS OF RIPRAP DESIGN
UPPER WOONSOCKET LOCAL PROTECTION PROJECT
BLACKSTONE RIVER

| | Standard Project Flood Q = 30,000 cfs | | | | | Moderate Flood Q = 15,000 cfs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Depth (Y) | V (ft/sec) | EG Line (ft/ft) | Slopes | $D_{50}$ min.* (ft) | Depth (Y) | V (ft/sec) | EG Line (ft/ft) | Slopes | $D_{50}$ min.* (ft) |
| 1+00 | 19.5 | 10.00 | 0.00151 | 1 on 2.0 | 0.55 | 12.7 | 8.15 | 0.00162 | 1 on 2.0 | 0.40 |
| 25+00 | 25.3 | 8.60 | 0.00084 | " | 0.40 | 13.8 | 7.50 | 0.00125 | " | 0.40 |
| 35+00 | 22.0 | 8.40 | 0.00121 | " | 0.50 | 14.2 | 7.25 | 0.00119 | " | 0.42 |
| 36+50 | 21.5 | 9.90 | 0.00139 | " | 0.56 | 14.0 | 8.50 | 0.00164 | " | 0.45 |
| 42+50 | 22.0 | 9.50 | 0.00125 | " | 0.55 | 14.1 | 8.40 | 0.00159 | " | 0.45 |
| 47+75 | 22.8 | 7.80 | 0.00081 | " | 0.40 | 14.5 | 6.60 | 0.00095 | " | 0.25 |
| 55+00 | 23.7 | 7.25 | 0.00083 | " | 0.40 | 15.4 | 6.00 | 0.00092 | " | 0.30 |
| 60+40 | 24.4 | 6.90 | 0.00056 | " | 0.35 | 15.8 | 5.75 | 0.00063 | " | 0.25 |
| 61+60 | 24.0 | 8.00 | 0.00178 | " | 0.82 | 15.8 | 6.25 | 0.00078 | " | 0.25 |
| 66+50 | 24.7 | 7.80 | 0.00074 | " | 0.42 | 16.0 | 7.00 | 0.00096 | " | 0.30 |
| 72+75 | 24.2 | 9.75 | 0.00154 | " | 0.70 | 16.0 | 8.15 | 0.00169 | " | 0.50 |
| 75+00 | 24.2 | 11.25 | 0.00155 | 1 on 1.5+ | 0.95 | 15.9 | 8.75 | 0.00148 | 1 on 1.5+ | 0.60 |
| | | | | (1 on 1.75) | (0.80) | | | | 1 on 1.75 | 0.53 |

*From: Graphical Determination of Minimum $D_{50}$ for Graded Stone Riprap Channel Protection (Criteria from OCE draft report, April 1966)

*Left side of channel 1 on 1.75
Right side of channel 1 on 1.50

dikes and floodwalls leading to a 10-foot by 17-foot pressure conduit. The Mill River was similarly contained by the construction of a twin 12 by 21-foot pressure conduit which required dikes and walls extending from the conduit entrance to high ground. A general plan and profile of the project is shown on Plate A-6 and A-7. More detailed discussion of specifics can be found in the feature Design Memorandums for the project.

B. Design Floods

(1) The project was designed to protect against a Standard Project Flood on the rivers and earth dikes were built to provide 3 feet of freeboard above design flood levels. A detailed development of the Standard Project Flood (SPF) for the Lower Woonsocket Local Protection Project is contained in the project's Design Memorandum No. 1, Hydrology. In general, two SPF's were computed. The first was used to determine design criteria for the major features of the project along the Blackstone River and was developed by considering a standard project storm (SPS) centered over the entire basin with the resultant rainfall excesses applied to adopted unit hydrographs. The second SPF was developed by considering the SPS centered over the Mill and Peters River watersheds. The upstream project features along these two rivers were designed for the most adverse combinations of concurrent discharges from the design floods on the Blackstone and Mill and Peters Rivers. Table 4 contains pertinent peak discharges associated with these standard project floods.

(2) It is noted that recent (1975) unit graph studies for the Blackstone River consisting of a review of the 1955 flood hydrograph and an analysis of the more recent 1968 freshet, have indicated that the peak of the originally adopted unit graph may be somewhat low. However, a detailed review and analysis, possible resulting in a revised SPF, was not considered warranted at this time for it is concluded that protection to the level of the original SPF provides Woonsocket with a highly adequate level of protection.

(3) Effect of West Hill Reservoir: West Hill Reservoir, located on the West River and completed in 1960, would effect reductions on Blackstone River flows in Woonsocket. At Woonsocket, upstream of Mill and Peters Rivers, the SPF peak of 36,500 cfs would be reduced to 33,000 cfs by West Hill Reservoir. Downstream of the Mill and Peters Rivers, West Hill Reservoir would reduce the SPF from 43,500 to 40,000 cfs.

TABLE A-4

STANDARD PROJECT FLOOD

PEAK DISCHARGES

| | SPS Centered over Mill and Peters Rivers and Residual SPS Located over Blackstone River Basin (cfs) | SPS Centered over Blackstone River Basin (cfs) |
|---|---|---|
| Mill River | 8,500 | 7,000 |
| Peters River | 3,200 | 2,600 |
| Blackstone River | | |
| Upstream of Mill & Peters Rivers | 34,800 | 36,500 |
| Downstream of Mill & Peters Rivers | 43,500 | 43,500 |
| Concurrent Mill River flow at time of Blackstone River Peak | 7,200 | 5,700 |
| Concurrent Peters River flow at time of Blackstone River Peak | 2,000 | 1,600 |

C. Interior Drainage

(1) Description: The Lower Woonsocket Project has two protected areas that required provisions for drainage of interior runoff. The area lying generally on the north side of the Blackstone River is referred to as the Social District and that area on the south side, the Hamlet District. The Social District has a total drainage area of 295 acres but because of small diversions the effective drainage area to the line of protection is about 239 acres. The Hamlet District has a total drainage area of 185 acres less a maximum diversion capacity of 55 cfs from the area. Both areas would be currently classified as "Class I" as defined by EM 1110-2-1410. More detailed hydrologic descriptions of the two areas was presented in the feature design memoranda for the project.

(2) Gravity Outfalls: Gravity drains from both areas were sized to discharge the 100-year frequency storm runoff from the interior areas, with a coincident low river stage. This design meets current gravity capacity requirements for "Class I" areas as defined in the referenced Engineering Manual.

(3) Pumping Stations: Pumping stations were designed to pass the two-year frequency storm runoff with a design river stage and maintain ponding levels to an acceptable minimum (ponding level 121 feet msl in Hamlet District and 120 feet msl in Social District). Pumping capacity was based on the required frequency of pumping, rainfall rates during historic floods, and pumping station cost versus potential interior damage. The selected capacity of the Hamlet station was 125 cfs against low head design conditions (river elebation 119.6 feet msl) and 65 cfs against high head design condtions (river elevation 127.2 feet msl). These are equivalent to runoff rates of 1 inch and 0.65 inches, respectively, and represent the total inflow expected minus the 55 cfs diversion at Davidson Street and the effects of ponding. The Social station has a capacity of 250 cfs at river elevation 122.0 feet msl and 170 cfs at river elevation 132.0 feet msl. These are equivalent to 1.0 inch and 0.7 inches of runoff, respectively with the selected pump capacities, a five-year frequency storm runoff coincident with a design river flood would produce ponding to about 123 and 122 feet msl in the Hamlet and Social Districts, respectively. These levels are considered to approximate stage "B" as defined in the referenced engineering manual.

(4) Pumping station activation for the Social and Hamlet District stations is required when the river level opposite each station reaches 115.75 feet msl and 116.25 feet msl, respectively. These stages have frequencies of approximately two years for the Social District and four years for the Hamlet District. The facilities have functioned satisfactorily since project completion, most noticeably during the March 1968 freshet. During these periods of operation no problems that would affect the satisfactory performance of the facilities have come to light.

(5) It is noted that appropriate zoning and building codes should be adopted by the city to insure that new buildings in the interior areas have floor grades high enough to prevent increased damage in the event shallow ponding should occur in the protected areas.

D. Riprap Analysis

(1) Riprap sizing was reviewed using the current tractive force criteria, referenced in the upper Woonsocket discussion. Minimum $D_{50}$ sizes were computed for selected locations along the Blackstone, Mill and Peters Rivers and the results of this analysis

are tabulated in Table A-5. The high $D_{50}$ values computed for the Peters River are caused by a steep channel gradient with resulting high velocities. Under design flow conditions, velocities in the Peters River are in the order of 8.5 to 10 fps throughout most of the channel with certain isolated areas having velocities as high as 13 fps. The entrance to the Peters River conduit required special consideration since tractive force criteria does not apply in this reach due to accelerating flow conditions. The effect of these high velocities, resulting in large minimim $D_{50}$ sizes, may prove more destructive to the stone riprap protection than the tractive forces in the channel proper. During the 1968 freshet many stones of the riprap at the conduit entrance were dislodged and carried downstream into the conduit. Witnesses claimed the stones could be heard hammering against the floor, walls and roof of the conduit. No similar displacement of riprap occurred upstream of the entrance.

(2) Tractive forces are relatively low on the Mill River, partially due to the backwater effect from either the hydraulic control at the entrance to the conduit or from the mainstem Blackstone River. Though the computed tractive force is low in this reach, it is recommended that, in future designs for urban areas, minimum $D_{50}$ be at least 0.8 feet for the purpose of reducing vandalism.

(3) This hydraulic analysis and resulting $D_{50}$ minimum information serves as the basis for further investigation of existing riprap adequacy by the Foundations and Materials Branch of the Engineering Division.

E. Problem Areas

(1) General: During the recent inspection of the Lower Woonsocket Project four problem areas were noted. Two are located on the Mill River, and one each on the Peters and Blackstone Rivers. Plate A-1 shows the locations of these areas with respect to the project.

(2) Mill River: Locations A and B are at the upstream end of the project on the Mill River and represent a ramp cut in the channel side slope and two blocked catch basins, respectively. The ramp located on the right side of the channel approximately 200 feet donwstream from the upper limit of the project was cut to allow access to the channel for the removal of silt from various locations along the channel. As a result riprap on the side slope was displaced and the natural bank soils are exposed and subject to erosion. No danger is presented to adjacent properties, as the land beyond the top of the bank is within the design flood storage area.

TABLE A-5

HYDRAULIC ANALYSIS OF RIPRAP DESIGN
LOWER WOONSOCKET LOCAL PROTECTION PROJECT
BLACKSTONE, MILL AND PETERS RIVERS

| Sta | Depth (y) | V (fps) | Friction Slope (ft/ft) | Side Slopes | $D_{50}$ Minimum (2) (ft) |
|---|---|---|---|---|---|
| | | Blackstone River (SPF) Q = 33,000 cfs (1) | | | |
| 125+50 | 24.50 | 7.6 | 0.00068 | 1 on 2.0 | 0.40 |
| 135+50 | 28.53 | 7.3 | 0.00074 | 1 on 2.0 | 0.45 |
| | | Blackstone River (SPF) Q = 40,000 cfs (1) | | | |
| 155+00 | 24.10 | 11.5 | 0.00116 | 1 on 2.0 | 0.75 |
| 163+50 | 25.80 | 11.1 | 0.00138 | 1 on 2.0 | 0.65 |
| | | Peters River (SPF) Q = 3,200 cfs | | | |
| 1+50 | 8.7 | 11.90 | 0.0067 | 1 on 2.0 | 1.10 |
| 2+10 | 8.4 | 9.84 | 0.0039 | 1 on 2.0 | 0.65 |
| 3+80 | 9.2 | 8.44 | 0.0028 | 1 on 2.0 | 0.50 |
| 5+25 | 9.3 | 10.24 | 0.0047 | 1 on 2.0 | 0.85 |
| 8+50 to 9+50 | - | 13.0± to 20.0± | | - | 1.2 to 2.0 (3) |
| | | Mill River (SPF) Q = 8,500 cfs | | | |
| 11+00 | 17.92 | 4.6 | 0.00005 | 1 on 2.0 | 0.20 (4) |
| 15+60 | 22.46 | 4.2 | 0.00024 | 1 on 2.0 | 0.10 (4) |
| 18+70 | 23.72 | 4.1 | 0.00022 | 1 on 2.0 | 0.10 (4) |
| 19+45 | 24.38 | 3.5 | 0.00017 | 1 on 2.0 | 0.10 (4) |

(1) SPF upstream of Mill and Peters River Q = 33,000 cfs, downstream Q = 40,000 cfs

(2) From "Graphical Determination of Minimum $D_{50}$ for Graded Stone Riprap Channel Protection" (Criteria from OCE draft report April 1966)

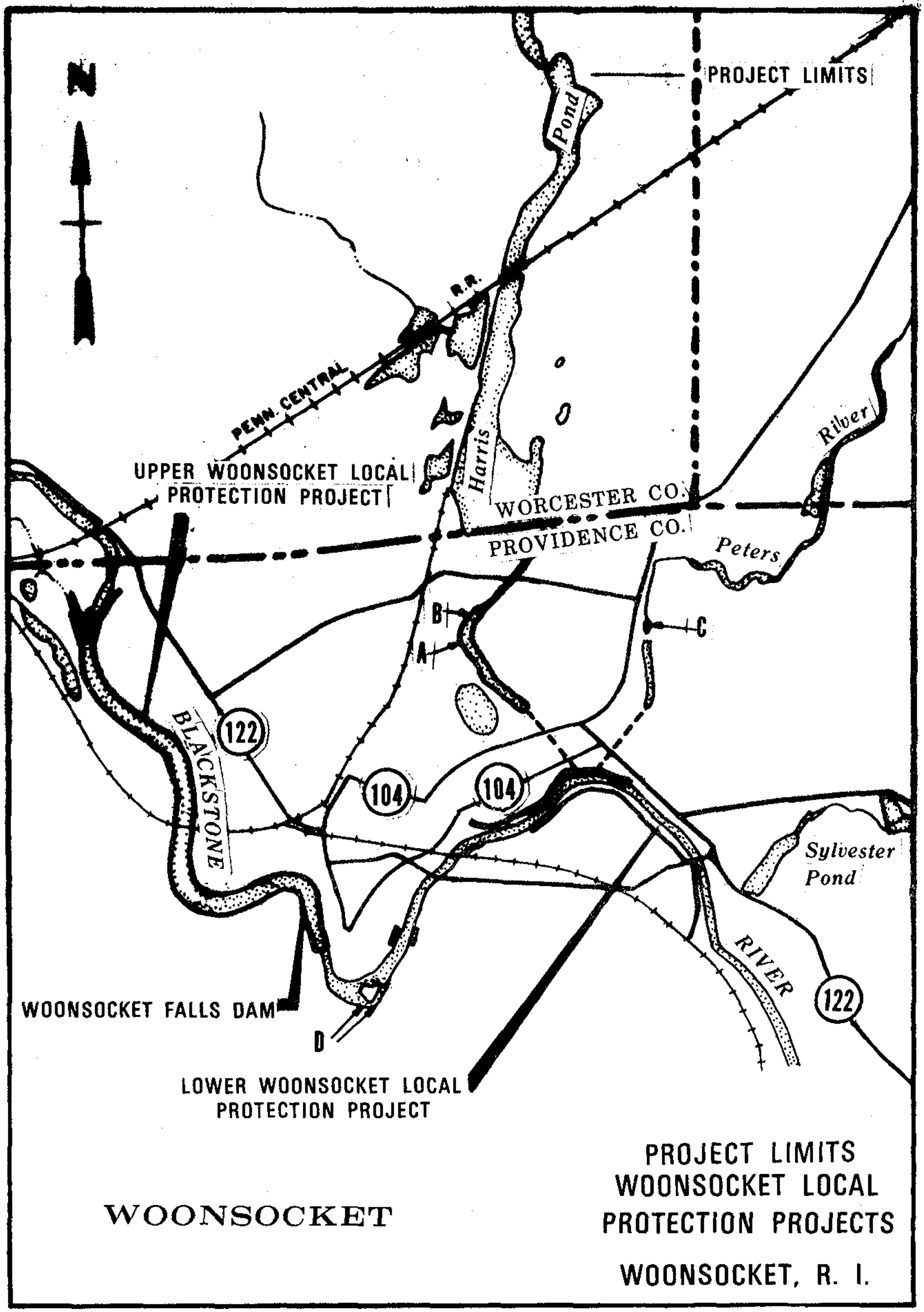
(3) Criteria set forth in Hydraulic Design Criteria, Sheet 712-1, (revised September 70) "Stone Stability, Velocity vs Stone Diameter", was used in reach 8+50 to 9+50 due to turbulent flow conditions.

(4) $D_{50}$ minimum = 0.80 recommended to minimize vandalism

The potential problem would be progressive ravelling of the riprap and widening of the area subject to erosion. In the event of high flows, this could result in extensive repairs being required. Personnel from the Project Operations Branch of Operations Division are aware of this condition and the reasons for it and have been assured by the city that now that the silt removal project is completed, the channel slope will be restored to its original condition. The catch basins, also on the right bank are located immediately downstream from the project limit and are intended to intercept interior runoff for conveyance to the river. During flood events the catch basins have become clogged with debris and when this occurs the interior runoff ponds on the right bank and then flows overland and down the embankment into the channel. This overbank flow could be structurally detrimental to the riprap protection. It is recommended that the city of Woonsocket enclose these two catch basins with a concrete box and trash bar to allow for easier maintenance of the drainage conduit.

(3) Peters River: Location C is upstream on the Peters River beyond the project limits. The potential problem is the filling of a portion of a pond formed by an old concrete dam sited immediately upstream of the Mill Street bridge. The height of the fill above the water surface is approximately 15 feet. This fill does not directly effect the project on the Peters River. However, because of the fill material the width of the pond is narrowed and should the fill slough off it is conceivable that it might block flows in the river. This could result in an increase in upstream water surface elevations, especially during periods of high flows, and might cause some of the water to "short circuit" the project by flowing down Social Street into the lower Social District area. At the present time the owner of the property adjacent to the pond has requested permission from the city to remove the old dam.

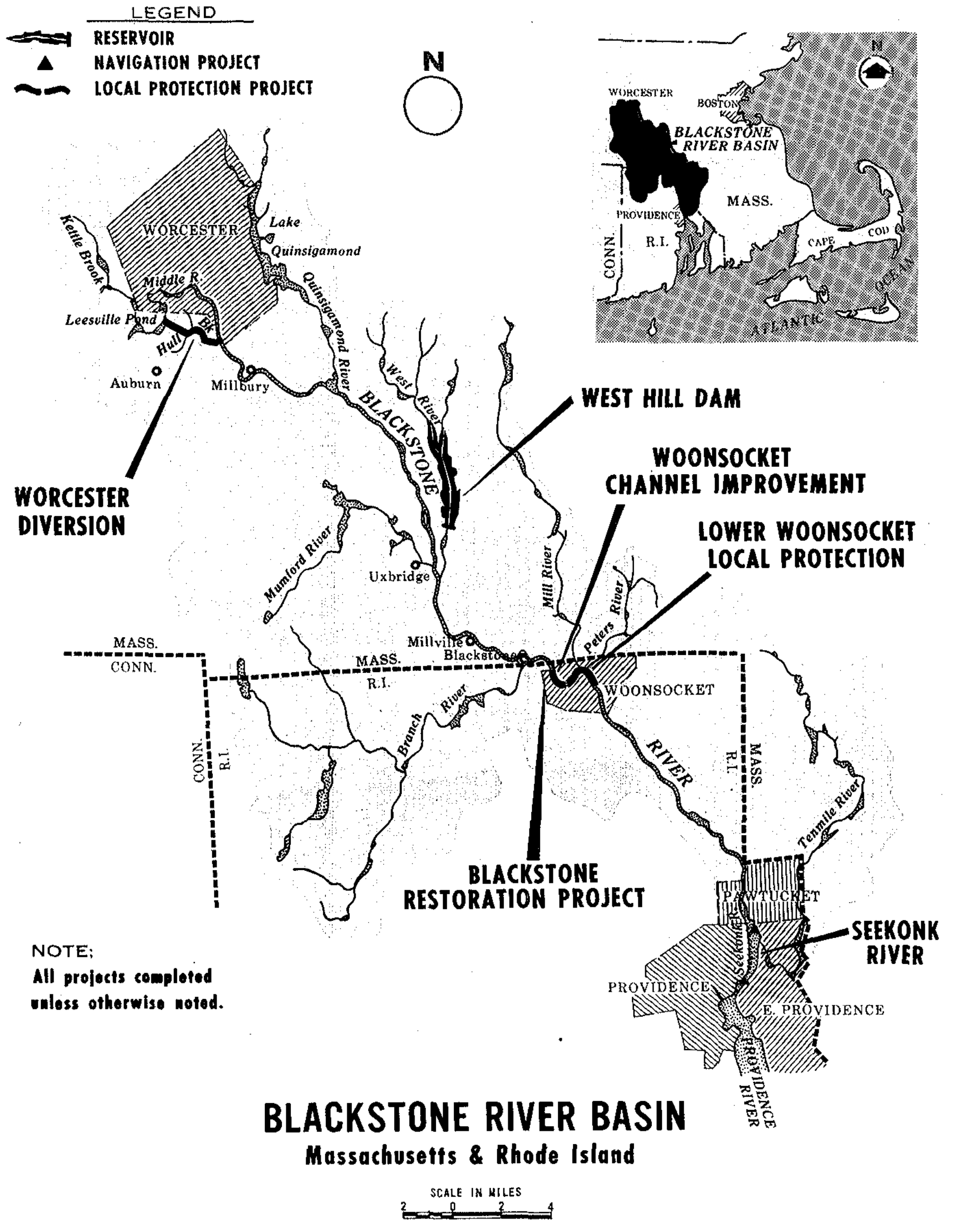
(4) Blackstone River: A minor erosion problem, location D on the exhibit, is on the outer bank of the Blackstone River downstream of the South Main Street bridge. This location is actually situated between the Upper and Lower project limits where the river makes a sharp bend from a southerly course to a northeasterly one. The outer bank is a steep, high bluff surmounted by a residential area. No remedial repairs are warranted since the erosion poses no threat to adjacent properties at this time but the erosion should be monitored in conjunction with future semi-annual inspections of the project features.



N
PROJECT LIMITS
Pond
Harris
R.R.
PENN. CENTRAL
UPPER WOONSOCKET LOCAL
PROTECTION PROJECT
WORCESTER CO.
PROVIDENCE CO.
River
Peters
B
A
C
BLACKSTONE
122
104
104
Sylvester
Pond
RIVER
122
WOONSOCKET FALLS DAM
D
LOWER WOONSOCKET LOCAL
PROTECTION PROJECT
WOONSOCKET
PROJECT LIMITS
WOONSOCKET LOCAL
PROTECTION PROJECTS
WOONSOCKET, R. I.


PLATE A-1

*NOTE: Delineation of streams on map is limited to major streams or to those having existing project or current study*




NOTE:
**All projects completed unless otherwise noted.**

# BLACKSTONE RIVER BASIN
## Massachusetts & Rhode Island

CORPS OF ENGINEERS

U. S. ARMY

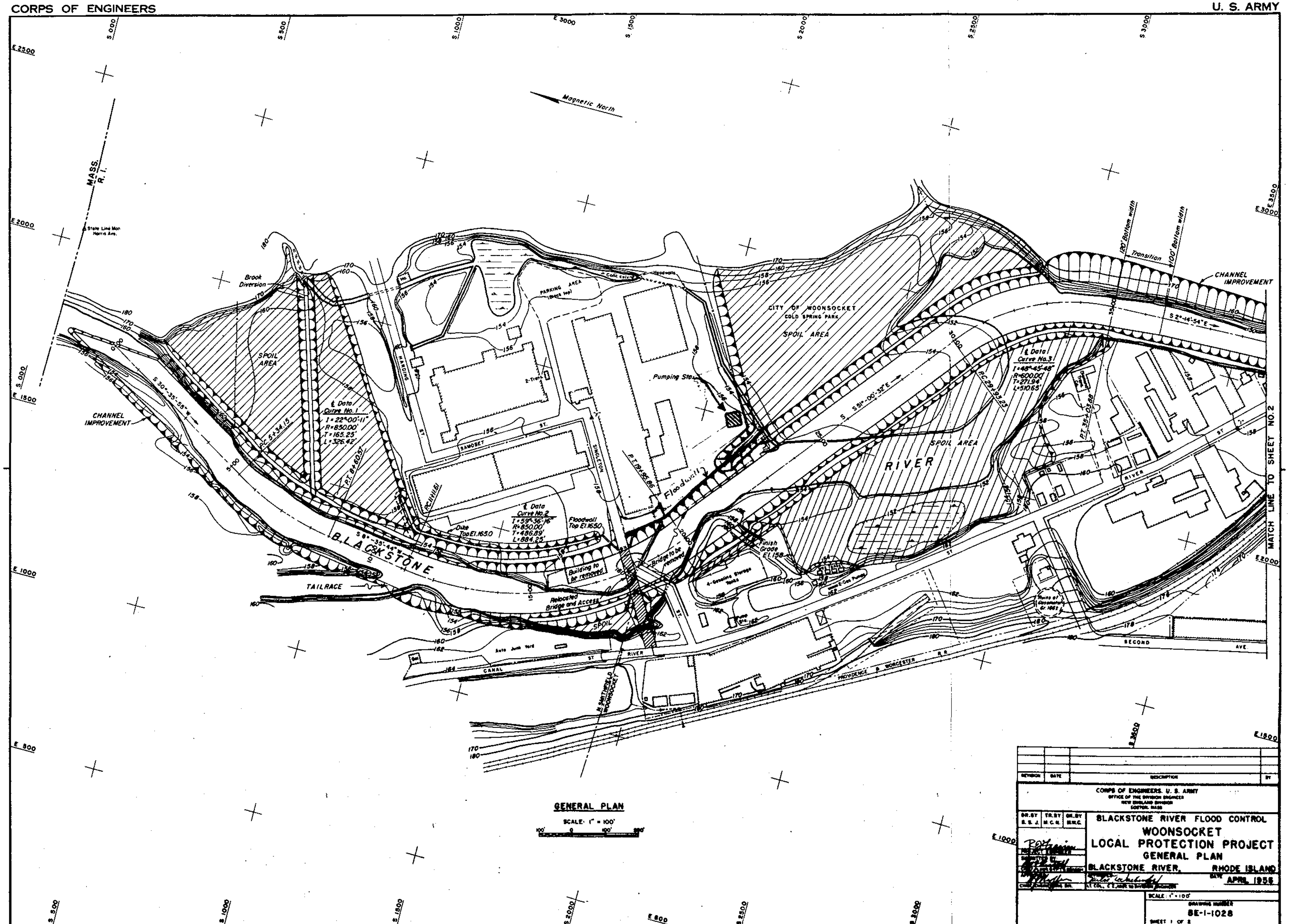



PLATE A-3

CORPS OF ENGINEERS U. S. ARMY

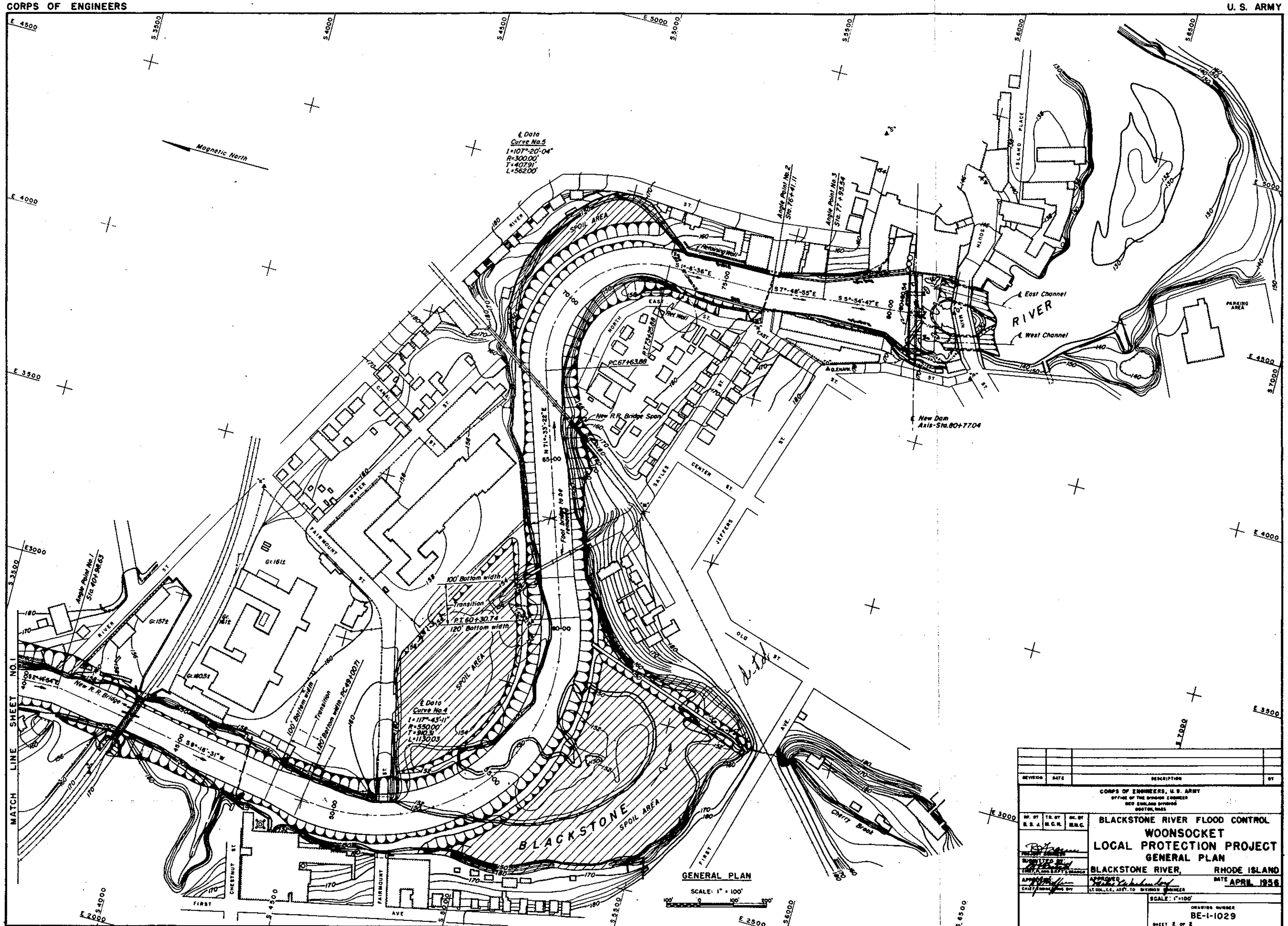
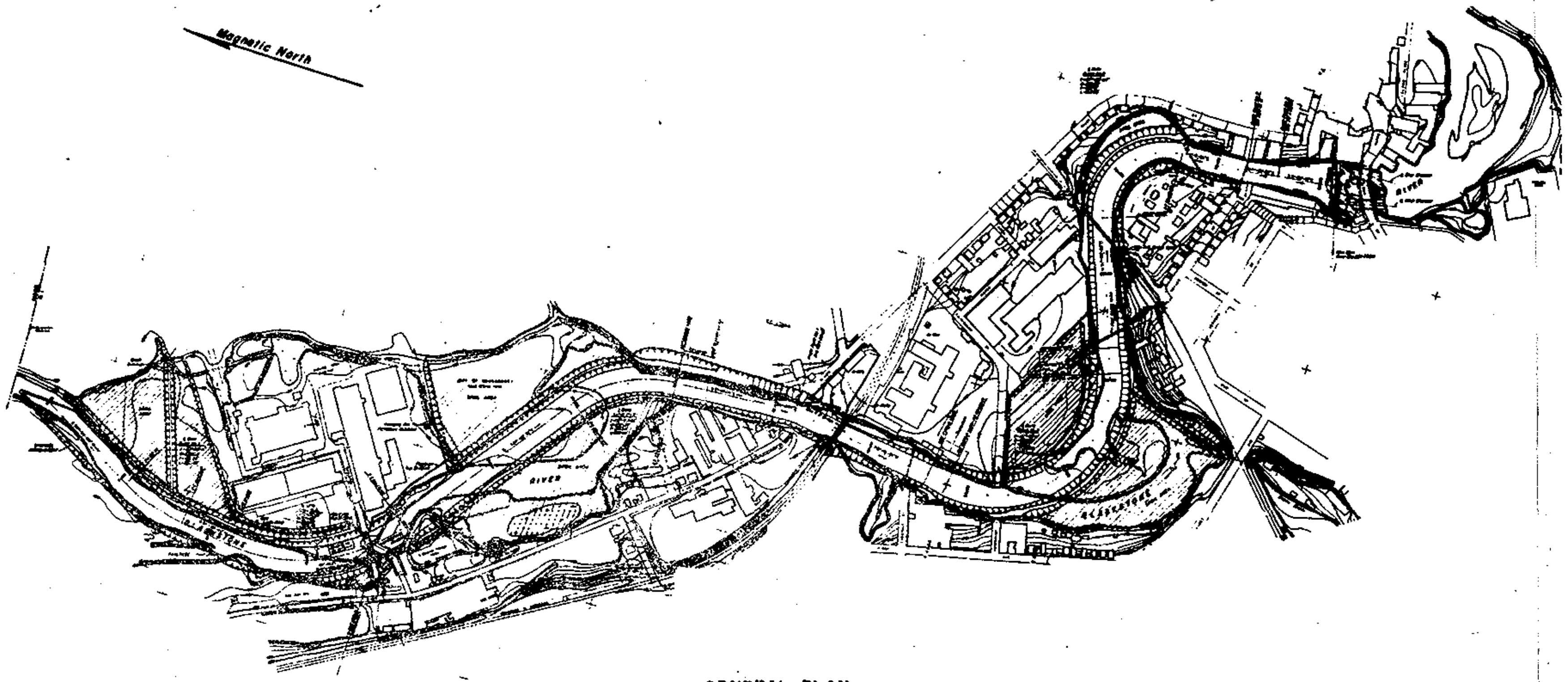
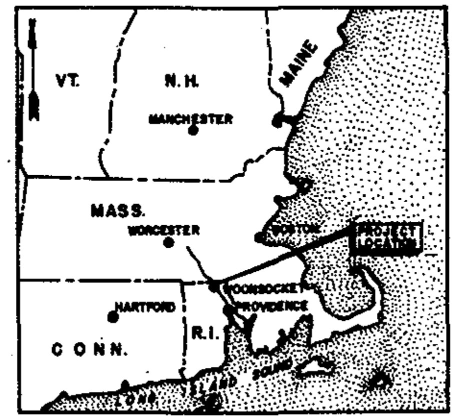



PLATE A-4

CORPS OF ENGINEERS U.S. ARMY

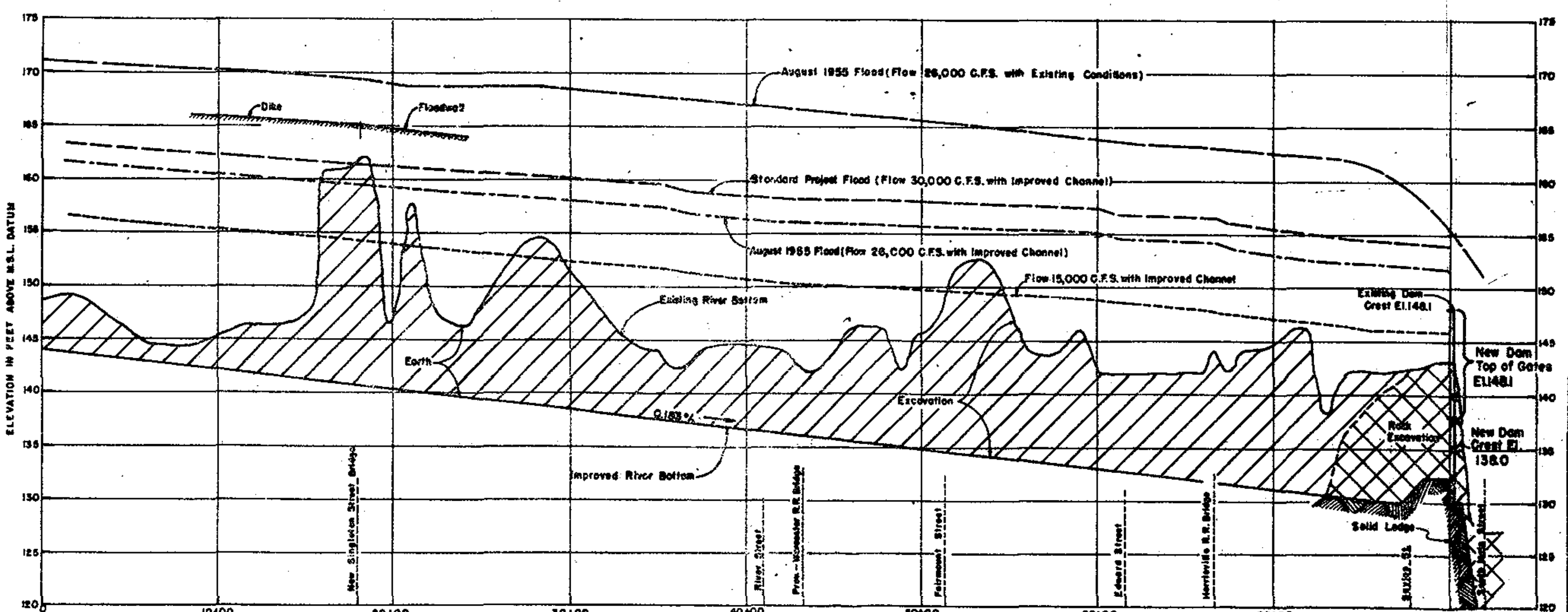



GENERAL PLAN
SCALE IN FEET




LOCATION MAP
SCALE IN MILES

NOTE
*See Plate No. 2-9; for profiles from Dam through South Main St. Bridge.*




PROFILE
SCALE HOR. 1" = 300' VERT. 1" = 5'

| REVISION | DATE | DESCRIPTION | BY |
|---|---|---|---|

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

DR. BY J.D. TR. BY A.J.H. CK. BY G.R.B.

BLACKSTONE RIVER FLOOD CONTROL
WOONSOCKET
LOCAL PROTECTION PROJECT
GENERAL PLAN AND PROFILE
BLACKSTONE RIVER RHODE ISLAND
DATE MAY, 1958

SCALE AS SHOWN
DRAWING NUMBER BE-1-1045
SHEET 1 OF 1

PLATE A-5

CORPS OF ENGINEERS U.S. ARMY

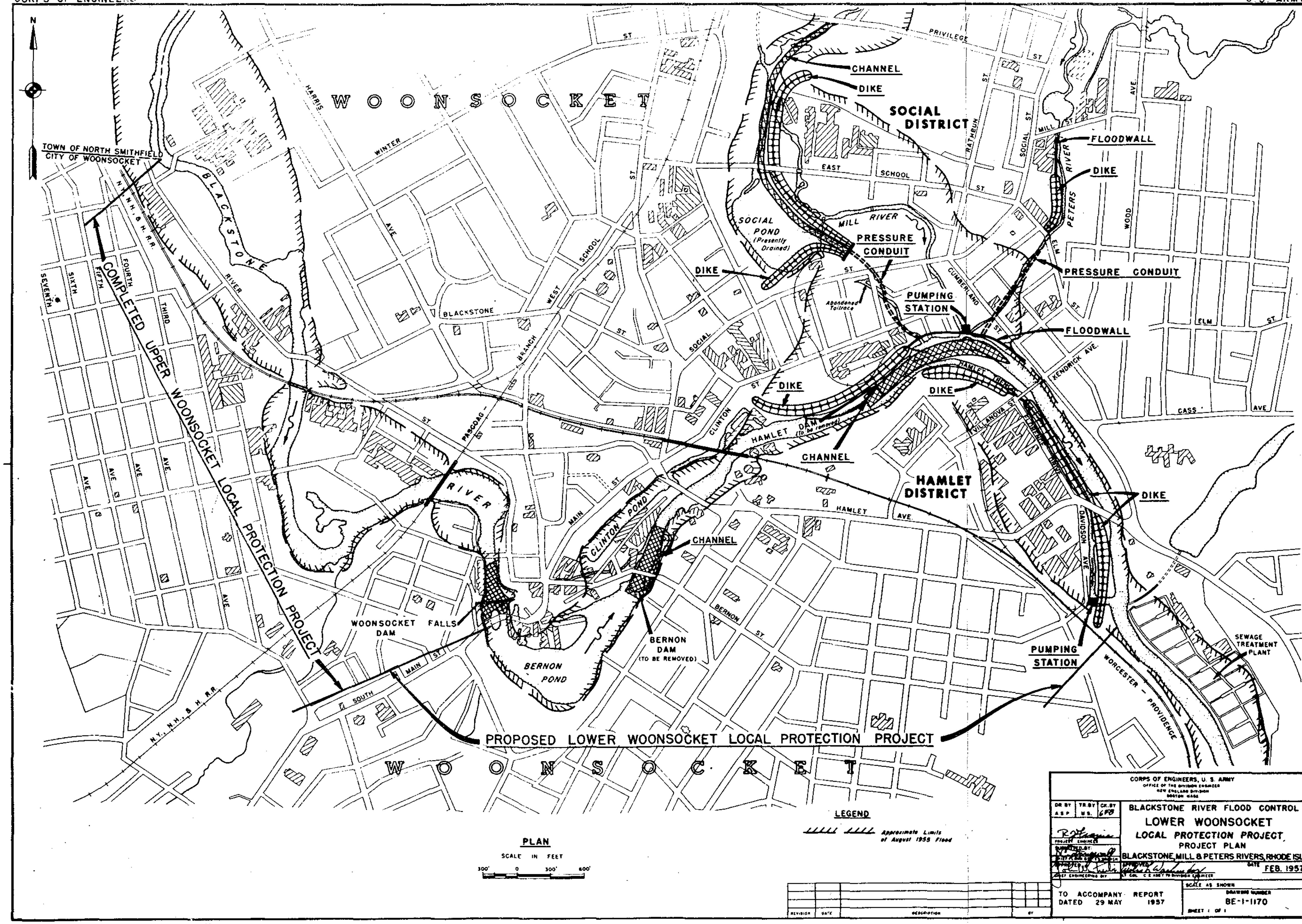



PLATE A-6

CORPS OF ENGINEERS U. S. ARMY

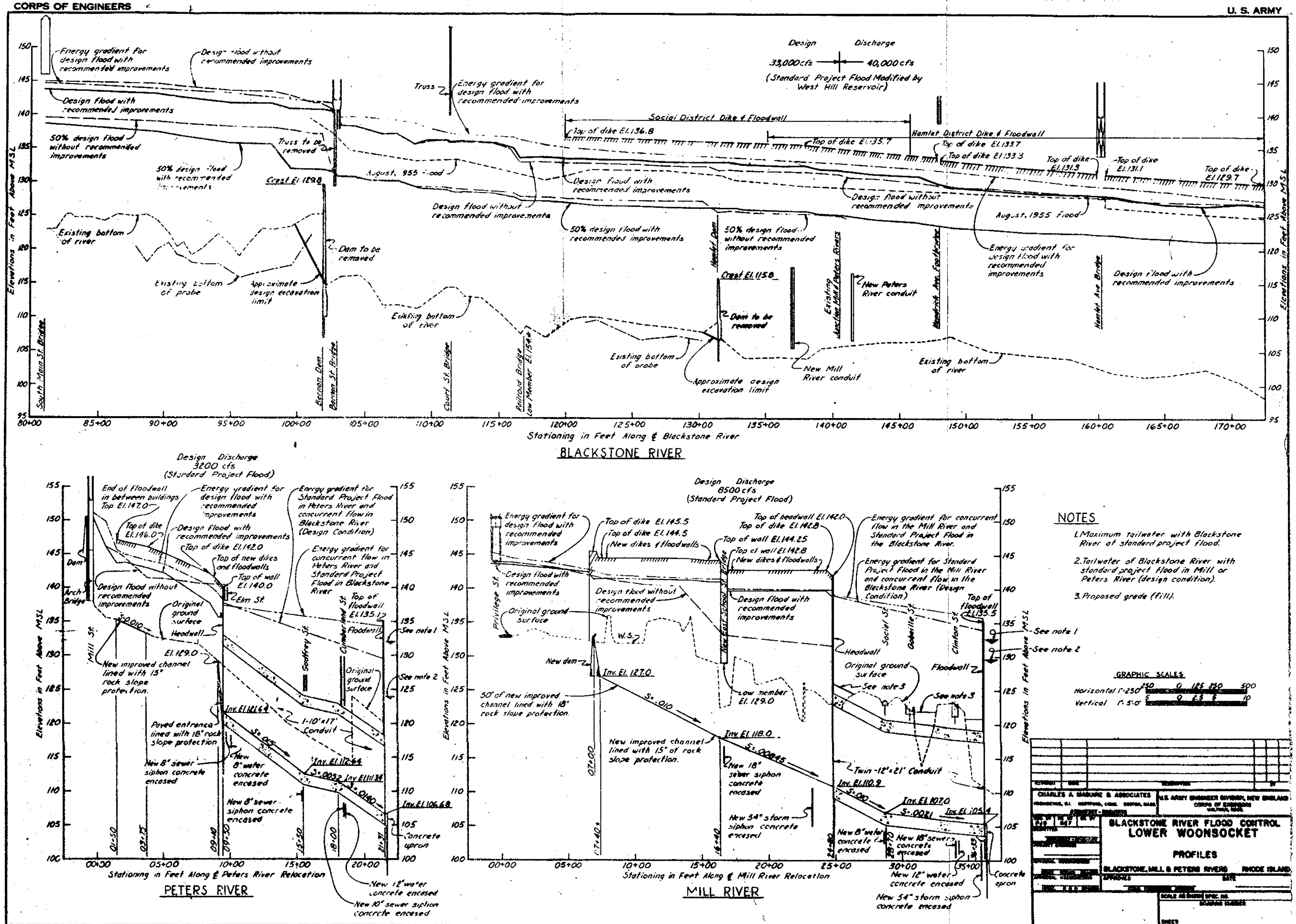



PLATE A-7

# SECTION B

## STABILITY ANALYSIS

SECTION B

STABILITY ANALYSIS

TABLE OF CONTENTS

WOONSOCKET LOCAL PROTECTION PROJECTS
WOONSOCKET, RHODE ISLAND

STABILITY ANALYSIS
JULY 1976

A. UPPER WOONSOCKET PROJECT

1. General. The Woonsocket Local Protection Project, completed in 1960, consists of approximately 8300 linear feet of channel realignment and improvement on the Blackstone River in its upper reaches of Woonsocket, Rhode Island. Material from the channel excavation was used as spoil fill to raise low lying areas adjacent to the river above the flood stage throughout most of this reach; consequently, dikes and floodwalls occur in relatively short reaches. A water control dam was constructed at the lower end of the project located just upstream of Main Street for mill water supply.

2. Floodwalls. There is one T-type floodwall 316 feet long on the project. It is on the left bank between approximate Stations 18+50 and 21+80 its height is 6 feet above the landside ground surface.

a. Design Criteria. Loading conditions, design assumptions, and other design criteria are based on the applicable parts of Engineering Manual for Civil Works, EM 1110-2-2501 "Wall Design - Floodwalls" dated January 1948.

b. New Criteria. Change 2, EM 1110-2-2501 with supplement dated 15 March 1961 contains additional design criteria developed as a result of full-side floodwall tests. The floodwall design has been checked against the new design criteria and found to be satisfactory.

c. Inspection and Evaluation. The floodwall was inspected on 16 April 1976 and found to be in satisfactory condition.

3. Dikes. Dikes on this project are situated as follows:

Dike 1 - Sta. 10+00 to 18+00, left bank length 800 ft., height 7 ft.
Dike 2 - Sta. 21+80 to 24+20, left bank length 240 ft., height 7 ft.
Dike 3 - Sta. 17+00+ right bank (transverse to river channel) length 150 ft., height 4 ft.
Dike 4 - Sta. 17+00+ right bank (transverse to river channel) length 110 ft., height 5 ft.

a. Design Features. All dikes are designed with 1 on 2 side slopes with a 10-foot top width for Dikes 1 and 2 and a 5-foot top width for Dikes 3 and 4. The top elevations of the dikes provided a 3-foot freeboard above the standard project flood. The dikes consist of an inclined impervious blanket on the riverside slope over random fill obtained from required excavations. The landside slopes and the riverside slopes in the freeboard zone are topsoiled and seeded. Riverside slopes below the freeboard are protected by 12 inches of riprap over 6 inches of gravel bedding. See paragraph "Channel Slopes" for riprap description. The dike design meets current design criteria.

b. Inspection and evaluation. On 16 April 1976, all dikes were inspected and showed no sign of unsatisfactory performance.

4. Channel Slopes. Channel side slopes were formed by excavation into natural soils, construction of spoil fill area and construction of dikes and floodwalls. All channel side slopes are 1 vertical on 2 horizontal except between Sta. 72+50 and the dam at Sta. 76+70 where channel restrictions and rock excavation dictated steeper slopes of 1 on 1.75 on the right bank and 1 on 1.5 on the left bank. All channel slopes, except those in rock excavation, are protected against erosion and scour with riprap on bedding material.

a. Riprap Criteria. Stone for riprap was sized in accordance with Civil Engineering Bulletin 52-15 (later changed to EM 1110-2-3901) for the velocities computed for the standard project flood flow (30,000 c.f.s.). The riprap on the 1 on 2 slopes consists of 12 inches of dumped rock placed on 6 inches of gravel bedding. The dumped rock terminated in a rock toes extending 14 feet into the channel bed. The dumped rock is reasonably well-graded from a maximum size of approximately 150 pounds to a minimum size of approximately 2 inches. Derrick stone weighing not less than 500 pounds were used on slopes steeper than 1 on 2.

b. New Criteria. Design criteria for riprap revetment has been changed and is now contained in EM 1110-2-1601, dated 1 July 1970. The existing revetments were evaluated in the light of current criteria. It was found that the riprap meets the new criteria for stone size.

c. Inspection and Evaluation. All riprap revetment was inspected on 16 April 1976. The riprap was found to be performing satisfactorily except where vandalism has occurred. In readily accessible areas, the slopes have been denuded by children throwing the stones into the river channel. This condition was noted under bridge abutments and on the left bank adjacent to the city playground, (Sta. 25+00 to 33+00). The city of Woonsocket has been replacing riprap on these denuded areas and is, in general, using larger size stone in an effort to discourage the vandalism.

B. LOWER WOONSOCKET PROJECT

1. General. Construction of the Lower Woonsocket Local Protection Project was started in 1963 and completed in 1967. The project starts about 3,700 feet downstream of the Woonsocket Local Protection. Completed in 1960 and consists of dikes and floodwalls along the Blackstone River and dikes, floodwalls and box conduits along two tributaries, the Mill River and the Peters River.

2. Dikes. Dikes along the Blackstone River extend about 1,800 feet on the left bank and 3,200 feet on the right bank. The maximum height of these dikes above the landside toe is about 13 feet. The dikes along the Mill River have a total length of about 2,400 feet and are the highest on the project extending up to 20 feet above the landside ground surface. On the Peters River, there is one dike about 650 feet long with a maximum height of 9 feet.

a. Design Criteria. Design criteria as set forth in the pertinent sections of Engineering Regulations for Civil Work Construction EM 1110-2-2300 "Earth Embankment" and regulations and bulletins referred to therein were followed in the design of the dikes for this project. No significant change in design criteria has taken place since the design of the project, except for the selection of rock sizes for riprap as discussed in paragraph 2 b below.

b. Design Features.

(1) General. All dikes on this project are of the rolled earth fill type with an inclined impervious blanket and have a 10-foot top width, 3 feet of freeboard. Side slopes are 1 vertical on 2 horizontal. Riverside slope protection consists of riprap on a gravel bedding layer. Average height of the dikes above ground is about 11 feet along the Blackstone River, 20 feet along the Mill River, and 8 along the Peters River.

(2) Seepage control. Seepage through the dikes is controlled by the arrangement and characteristics of the various fill materials. Foundation seepage under the dike is controlled by (1) landside toe drains (2) extending the impervious fill sections to the bottom of the river and (3) an inspection trench backfilled with impervious fill material. The landside toe drain was eliminated where the height of the dike was less than 8 feet.

(3) Slope stability. Both the riverside and landside embankment slopes for all dikes were established as 1 on 2. These slopes were analyzed for all critical conditions and are considered satisfactory.

(4) Slope protection. The landside slope and the freeboard portion of the riverside slopes are protected by grass. The riverside slopes below the freeboard are protected by a layer of riprap on a gravel bedding layer. Criteria set forth in EM 1110-2-3901 were used to determine stone size and layer thickness requirements for the riprap. A 12-inch layer with a maximum stone size of 150 pounds and an average size between 30 and 50 pounds was required on all slopes except along the Peters River and the Mill River upstream of East School Street. In these reaches, due to higher stream velocities, a 15-inch layer with a maximum stone size of 250 pounds and an average size between 50 and 80 pounds was required. For economy, a locally available crusher-run quarry rock with a maximum size of 120 pounds and an average size of between 50 and 80 was used for riprap throughout the project. In the reaches where a larger maximum size (250 pounds) was indicated, the layer thickness was increased to 3 feet to compensate for the lack of stone between 120 and 250 pounds. It was expected that some stones would be displaced before the slope protection became stabilized. Rock paving consisting of stone 100 to 700 pounds was placed at the entrance to the Peters River Conduit from Sta. 9+10 to 9+50.

c. New Criteria. Since the completion of this project, there has been no significant change in design criteria except for the selection of rock sizes for riprap. New criteria for riprap revetted slopes is contained in Engineering Manual EM 1110-2-1601, Hydraulic Design of Flood Control Channels, dated 1 June 1970. Under the new criteria, the D 50 (min) size rock was computed. The existing rock protection meets the new criteria except for reaches along the Peters River and on the Blackstone River downstream of the Peters River. Along the Blackstone, the differences are slight and considered insignificant. Along the Peters River, rock sizes determined in accordance with EM 1110-2-1610 and based on the new D 50 sizes are as follows:

ROCK SLOPE PROTECTION REQUIREMENTS - PETERS RIVER

| STA | D 50 (min) (ft.) | W 50 (lbs) | W 100 (lbs) | Layer Thickness (inches) |
|---|---|---|---|---|
| 1 + 50 | 1.10 | 125 - 210 | 300 - 700 | 24 |
| 2 + 10 | 0.65 | 35 - 50 | 70 - 180 | 15 |
| 3 + 80 | 0.50 | 15 - 25 | 40 - 90 | 12 |
| 5 + 25 | 0.85 | 60 - 90 | 120 - 300 | 18 |
| 8 + 50 | 1.20 | 200 - 300 | 400 - 1000 | 27 |
| 9 + 50 | 2.00 | 750 - 1100 | 1500 - 4000 | 42 |

Under the new design criteria, the required rock sizes at the beginning of the project (STA 1 + 50) and at the entrance to the Peters River Conduit (STA 8 + 50 to 9 + 50) are significantly larger than those used in construction of the project.

3. Floodwalls. The floodwalls on the Lower Woonsocket Project are as follows:

| Location | Length (ft.) | Height above ground Landside (ft.) | Height above ground Riverside (ft.) |
|---|---|---|---|
| Blackstone River | 1100 + | 13 | 13 to 30 |
| Mill River | 600 + | 12 | 12 to 25 |
| Peters River | 250 + | 7 | 7 |

The main floodwall section is located on the left bank of the Blackstone River from the Mill River outlet to approximately 200 feet upstream of Kendrick - Villanova Street footbridge. Additional walls are located at the upstream ends of both the Mill and Peters River conduits.

a. Design Criteria. Loading conditions, design assumptions, and other design criteria are based on the applicable parts of Engineering Manual EM 1110-2-2501 "Flood Walls".

b. Design Features. T-type floodwall sections have been used throughout the project. Type "B", a sloped base wall, is the typical floodwall section along the main river with a deeper type "A" wall with a horizontal base used at conduit outlets and at the Social Street Pumping Station. Varying heights of walls were required at transitions between "A" and "B" wall sections, at conduit entrances, and at the East School Street Bridge on Mill River. At the deeper sections of floodwalls adjacent to conduit entrances and exits, pumping stations, and bridge openings, steel sheet piling was used as a seepage cutoff made continuous with that using the conduit headwalls for protection against scour.

c. New Design Criteria. No significant changes in design criteria have occurred since these walls were constructed.

4. Channels. Channel realignment and improvements occur for a short reach on the Peters River and throughout the Mill River from the conduit entrance to the upstream end of the project. In these reaches, the channel bottom and sideslope are protected from erosion by riprap

placed on bedding material. The riprap is the same as used for riverside dike slopes described in paragraph 2 b above. The riprap layer thickness in the channel bottom is 2 feet in the Peters River, 2 feet in the Mill River, upstream of East School Street and 1 foot below East School Street.

5. Inspection and Evaluation. On 16 April 1976, all dikes, floodwalls, rock slopes and channel protection work were inspected. Deficiencies, as noted below, were observed or appear through the advent of new design criteria. The rock sizing coupled with the channel configuration at the approach to Peters River Conduit appears to create a potential danger area.

a. Peters River Channel. The channel approach to the conduit is a steep pitched slope, dropping 7.36 ft. in 40 feet horizontally. The side slopes are 1 on 2. The channel bottom and side slopes in the chute type approach are lined with 2 feet of rock paving on the channel bottom and 3 feet on the side slopes. The rock sizes range from 100 pounds to 700 pounds. During the flooding of 1968, stones from this rock paving zone were displaced; some of them being deposited inside the conduit. The stones were later removed from the conduit and the rock paving restored. Based on new criteria for stone sizes shown in paragraph 2c above the problems experienced in 1968 from a minor flood, the stone size at the entrance to the conduit is not adequate to withstand a standard project flood. Displacement of the stone during a flood could block the passage through the conduit causing overtopping and failure of the dike. A concrete lined structure should be considered as a replacement for the rock paving in the approach channel to the conduit.

b. Mill River Channel. Two catch basins located at approximately station 7 + 50 on the right bank of the Mill River channel are sometimes plugged with debris. As a consequence, the catch basins are by-passed and surface run-off flows down the channel slope to the river instead of through the drainage system as intended. The surface run-off has undermined the riprap revetted slope and dislodged rocks are strewn on the channel bottom. Corrective action - cleaning out and boxing in the catch basin, removing the displaced stone from the river bottom, and restoring riprap to the slope - is recommended. Immediately downstream of this area, a ramp has been cut in the channel side slope for equipment access. Slope erosion with rocks strewn on the channel bottom has also occurred in this area. Restoration and replacement of the riprap on the slope is recommended.

c. Social District Dike. A short reach of the riverside slope has been denuded of riprap by vandalism just upstream of the Mill River Outlet. Replacement of the riprap is recommended.

C. OTHER AREAS. During the inspection trip, bank erosion on the right bank of the Blackstone Ruver between the two projects was noted. The eroded area is in reach extending from 500 to 1000 feet upstream of the Bernon Street Bridge. The riverbank in this reach has a steep slope extending well above the standard project flood and, as such, presents no problem from overtopping. No remedial action is recommended at this time.